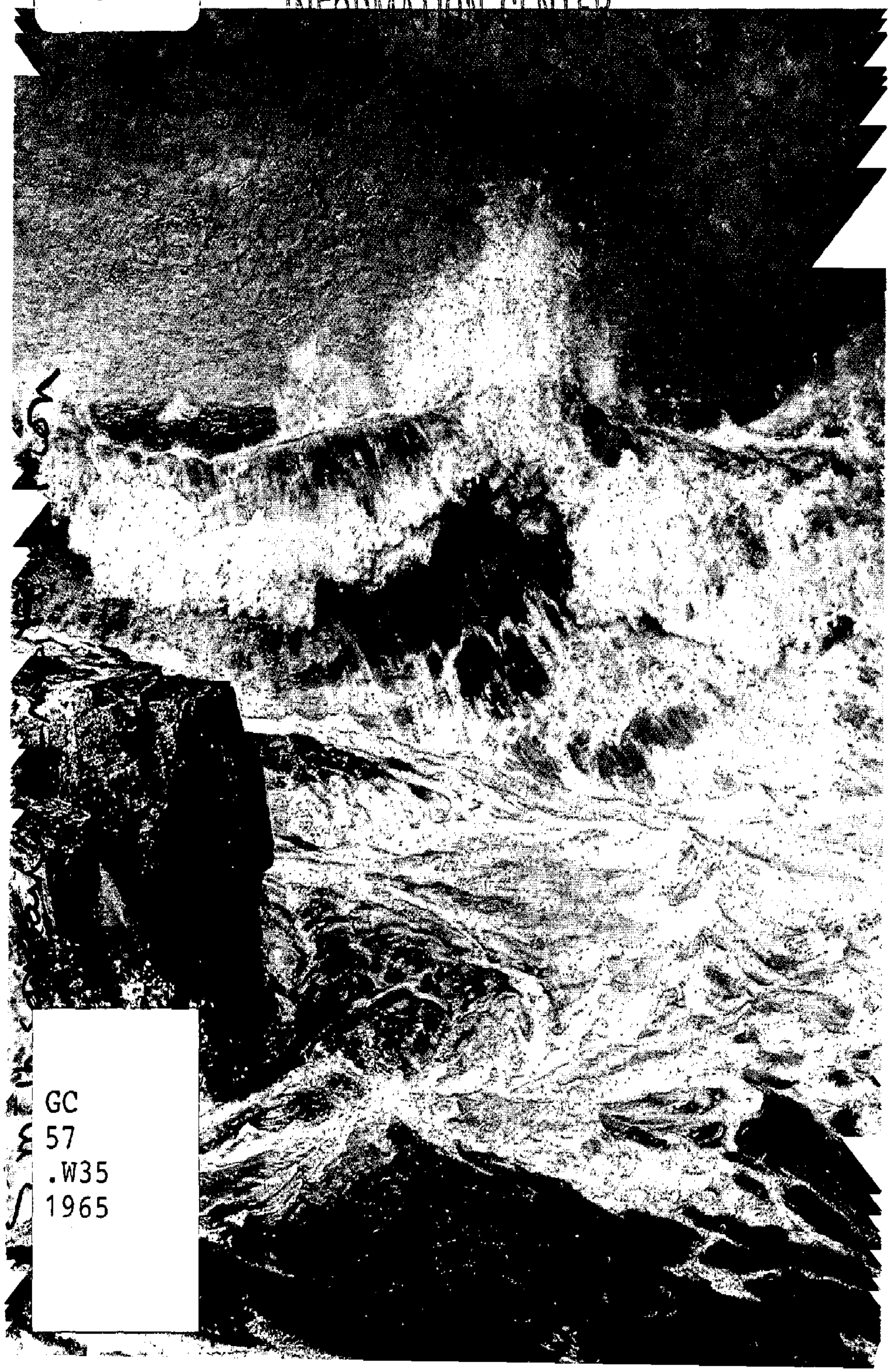
THE SMITHSONIAN INSTITUTION EDWIN A. LINK LECTURE SERIES

The United States and the World Ocean

by DON WALSH



Cover illustration: From oil painting "After a Northeaster," by Frederick Judd Waugh, in the William T. Evans Collection, National Collection of Fine Arts. Smithsonian photo.

Walsh, Don.

The United States and the World Ocean*

LT. COMDR. DON WALSH, USN

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From left, Dr. I. E. Wallen, Mr. Edwin A. Link, and Lt. Comdr. Don Walsh at the Second Annual Edwin A. Link Lecture, February 17, 1965, at the Smithsonian Institution. Smithsonian photo.

THE LECTURESHIP

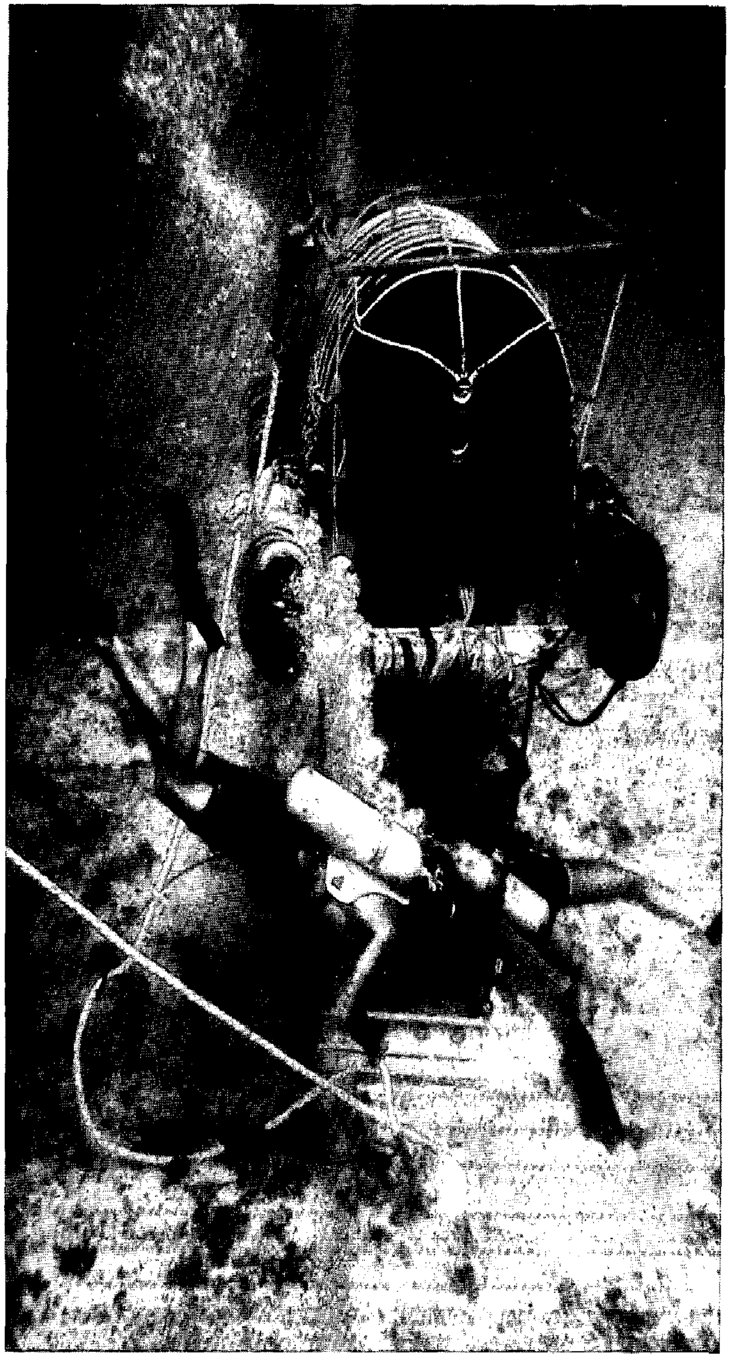
The Edwin A. Link Lectures are made possible by a grant from the Link Foundation in honor of its founder, Edwin A. Link, engineer, inventor, and explorer. They are administered by the Smithsonian Institution with the U.S. Office of Education as a cooperating agency.

THE LECTURE

This, the second lecture, given on February 17, 1965, at the Smithsonian Institution's Museum of Natural History, Washington, D.C., describes the varied programs of the United States in underseas exploration and the importance of the seas to mankind. Particular emphasis is given to the speaker's personal experience in deep-ocean exploration on board the U.S. Navy's bathyscaph *Trieste.*

THE LECTURER

On January 23, 1960, Lt. Comdr. Don Walsh, together with designer-pilot Jacques Piccard, descended in the bathyscaph *Trieste* to a depth of 35,800 feet in the Marianas Trench—the greatest depth yet explored by man. For this exceptional service, Commander Walsh was awarded the Legion of Merit. After continuing to work with the *Trieste* for several more dives, Commander Walsh was transferred to the *USS Sea Fox* in the Western Pacific and later to the *USS Bugara.* He recently has begun advanced study in oceanography at the Agricultural and Mechanical College of Texas.



In Edwin Link's "Man in the Sea Project" work is being carried out from a collapsible, pressurized undersea dwelling. Union Carbide Corporation photo.

The United States and the World Ocean*

LT. COMDR. DON WALSH, USN

IT IS AN HONOR and a privilege for me to appear on this distinguished platform to present the second annual Edwin A. Link Lecture. This annual lecture series, sponsored by the Link Foundation under the auspices of the Smithsonian Institution, alternates its attention between aerospace and oceanic subjects.

It is fitting that this series carries the name of Edwin A. Link, who exemplifies the "three-dimensional" explorer of our times. This remarkable person is a successful businessman, inventor, philanthropist, and explorer, and this lecture series is the perfect expression of tribute to his continuing contributions to his country.

As this is the first Edwin A. Link Lecture to deal with the oceans, I have decided to sketch a broad background of this vast subject, its importance, its challenges, and its opportunities. Thus, with the picture in place, later lecturers will add the color and the details which this brief exposure will not permit this evening.

"The United States and the World Ocean" may sound a bit grand at first, but let us consider that this title represents nothing more than an extension of our historical interest in seapower and maritime commerce—an interest which must now be stretched to include the three dimensions of the sea. We have stated that we will be second to none in outer space; we must also apply the same philosophy to "inner" space, for whoever controls the ocean also will control outer space.

* The opinions of the author are his own and do not necessarily reflect those of the Navy Department, the Navy as a whole, the Link Foundation, or the Smithsonian Institution.

THE IMPACT OF THE SPACE AGE upon the United States is hard to measure, but there is no doubt that the Mercury, Sputnik, Vostok, and Gemini successes have forever changed the horizons of our efforts. We have probed the Moon, Venus, and Mars, and we intend to have a man on the Moon by the end of this decade. We are surrounded by space symbols in our literature and television, and almost every other aspect of our everyday life. America looks upward . . . the world looks upward. But what of the launching pad, and this largest of all manned spacecraft, Earth? Have we forgotten something?

For well over 2,000 years of recorded history man has chronicled his exploration of his planet. The great voyages of exploration are legendary feats of courage and determination as man pushed back the frontiers of the unknown. The geographic barriers of the oceans were crossed, the highest mountains were climbed, steaming jungles were mapped, and the polar regions were surveyed. The literature documenting these great feats is well known to the curious youngster and the admiring adult. That which has not been personally visited by the intrepid explorer has been carefully analyzed by the relatively recent use of aerial surveys. The point is that if one were to reflect on our exploratory efforts, he would be tempted to say that we have just about finished with the business of exploration of our home planet and we are indeed ready to move off into the cosmos and new frontiers. Of course, this is not true, for all this exploration effort represents activity on only the terrestrial 29 percent of our planet; the remaining 71 percent is the virtually unexplored world ocean.

It is strange that we call our home planet "Earth," as its most pronounced feature, as compared with all the other known planets in our solar system, is that it is a *water* planet. When one of our astronauts first arrives on the Moon and casts his eyes homeward this fact will be very evident.

THE WORLD OCEAN is the term I like to use to describe the vast new frontier of inner space. A simple description of its dimensions and vast bulk is hard to convey in a brief word picture, but I will try. It covers an area nine times that of the Moon—and I could make a case for the fact that we probably know more about the Moon. Its volume is 14 times that of the land masses that project above it, and its average depth is about 2½ miles. If we could employ a giant bulldozer to smooth out the Earth's crust to a uniform thickness (like a billiard ball), the entire surface of our planet would be covered with water to a depth of *1½ miles*. Finally, the Pacific Ocean alone covers 34 percent of the globe—more than all the land masses put together. Indeed, this is a vast unknown frontier—a geographic frontier that man must explore, not in 2,000 years but in a decade or two to insure the continued, and I hope peaceful, march of civilization here on

Earth. This is the heart of my entire presentation—the urgency with which we attend to these "earthly" matters and the reasons why our country must be foremost in this effort.

For most of you, perhaps the most familiar utilization of the world ocean is that broad field of activity which I shall lump under the term "fishing." As a recreation, this activity enjoys an ancient and honorable history. Today, it is hard to match the thrill of sport fishing. The advent of the self-contained underwater breath apparatus (SCUBA) in the post-World War II years provided the sportsman and

Space exploration and oceanography advance together. An "outer space" contribution to oceanography is this photograph of the Atlantic Ocean at the Grand Bahama Bank, southeast of Andros Island, as seen from the orbiting Gemini V *spacecraft. Note the underwater detail. National Aeronautics and Space Administration photo.*

the curious with a new dimension of freedom to visit in the underwater environment. With the dramatic increase in leisure time available, more and more of our citizens will become devotees of this ocean sport, both from the surface and as inner spacemen in skin-diving rigs. It has been estimated that nearly eight-tenths of a billion dollars was spent in 1964 on deep-sea fishing.

However, while sport fishing is becoming a big industry in our country, it is not the most important aspect of fishing elsewhere in the world. In this sense I am referring to the production of food from the sea. It has been estimated that over half of the world's population is now suffering from nutritional starvation due to protein-poor diets. The best, cheapest, and most available source of animal protein for these 1½ billion hungry people is in the fish products from the world ocean.

Never in the history of mankind has a nation been so blessed with wealth, technology, and resources as ours has been. As the leader of the free world it is incumbent upon the United States to extend its technical assistance to the poorer nations, and our massive aid programs since World War II have provided this assistance. It is only natural that we extend these aids to help the poorer nations to gain their own sources of animal protein through technical assistance in the development of fisheries. This is not a cure-all for the total problem, as other factors of geography, processing, and transportation enter into the picture; but an accelerated fisheries development program by the rich nations for the poor nations could make vital contributions in reducing the influence of one of man's oldest neighbors here on earth—famine.

But, before we can aid, we ourselves must be proficient. Our own commercial fishing industry is in trouble. Last year (1964) for the first time in our history we imported more fish products than were produced by our own industry. In many cases these fish products were caught off our own shores, taken to a foreign shore, processed, and returned to our markets. In 1957 the United States was second largest in world commercial fisheries; today we are slipping past fifth place, behind Japan, Peru, Communist China, and the Soviet Union. This is not a small industry in our country. It is a billion-dollar-a-year retail business employing about 12,000 fishing vessels. The problem lies in our industry's inability to effectively compete with the large, well-endowed, and well-equipped foreign fishing fleets. Obsolescence and high operating costs have taken such a toll on our fishing industry that a vigorous government-assisted upgrading program will be required if we are to successfully get back into the competition. Happily, the problem is being recognized, and such measures should soon come into effect.

In the United States we derive most of our animal protein from relatively cheap terrestrial sources such as cattle, poultry, etc., and for this reason our per-capita consumption of fish products has remained at about 11 pounds per year for the past 30 years, with the increased demand for fish products due primarily to population growth. Consequently, we can see that, at this time, we do not require the products of the sea as our primary source of animal protein. Our obligation in this area is in the development of advanced technology so that we can become an exporter of fish products as a business, aid the poor nations in developing their fisheries, and develop this food resource for future generations of Americans.

One promising future development may be the creation in this country of fish farms for "aquaculture." The fishing industry of today is largely analogous to hunting, in that the fisherman makes no direct investment in the ocean environment but only takes from it. Direct control of the environment and "crop" is limited. On the other hand,

Dr. Porter Kier, a Smithsonian Institution scientist, uses SCUBA equipment to study life on the ocean floor. Photo by John Harms using Dr. Kier's equipment.

if he could be a "farmer" through the use of controlled conditions (such as enclosed ponds with controlled environments) he would be able to develop a more predictable return for his labors over his ocean-going contemporaries. For the foreseeable future the "hunter" approach will undoubtedly prevail due to the considerable problems involved in creating the required captive "oceans" for aquaculture. The application of the modern tools of fisheries biology and advanced marine technology can probably increase today's fisherman's catch by a factor of five. At a time when only 13 percent of the world's animal protein comes from the ocean, such an increase could represent a major economic boom to our fishing industry. This type of improvement, along with the development of fish farms, can put the United States back into competition as a leader among the maritime nations. A recent report of the National Academy of Sciences, "Economic Benefits from Oceanographic Research," estimates that an investment of 50 million dollars a year in this area would return 2 billion dollars a year within a decade.

Some of you may wonder about the role of plant life as a food source from the ocean. Actually, the relative benefits from the harvest of plant life versus fish forms are small. In some areas of the world, seaweed is harvested as a food source either for direct consumption (dried) or for processing into a constituent for other foods. In fact, most of us have probably unknowingly eaten seaweed products. The common California kelp (seaweed) is harvested along the West Coast on a regular basis and is processed into several products, one of which is used as a stabilizing ingredient in ice creams, whipped breads, and other "foamy" products. It is of interest to note that this particular kelp is one of the fastest growing plants in the world and can be harvested almost weekly.

THE OTHER PRINCIPAL RESOURCE of the ocean is its mineral deposits, which include minerals dissolved in seawater and those on and beneath the sea floor. While the present inventory of mineral resources found on land is still high, we must look to the sea for our future needs, as it is doubtful that we will be doing much in the way of commercial mining in outer space. Another important point is the development of strategic mineral resources as a backup against withdrawal of overseas supplies. The economic criteria is, of course, that the extraction of minerals from the sea be competitive with terrestrial methods. Until this occurs, industry will not enter this area with any great investment.

Today there are several mineral resources in this situation. The first that comes to mind is petroleum. The petroleum industry has many offshore drilling and pumping rigs in the Gulf of Mexico and off California's coast, and continued exploration by the industry is developing and expanding these activities. The Dow Chemical Company extracts magnesium from seawater at its massive facility on the Gulf Coast at Freeport, Texas. To give an appreciation of the magnitude of the process, this plant uses about one million gallons of seawater a minute. Most of the magnesium and bromine in the United States comes from the processing of seawater rather than from terrestrial sources. In addition, salt, sodium, and potassium are provided by treatment of seawater.

One of the most promising resources of the ocean to be exploited in the near future is that of phosphorite and manganese nodules having included metals such as cobalt, iron, etc. These nodules occur on the sea floor in fairly high-grade form. The phosphorites are valuable as a chemical fertilizer for agriculture use, while manganese is essential in the making of steel. Cost studies have shown that the development of phosphorite deposits off the California coast is entirely feasible for the West Coast phosphorite market and perhaps even for export to Asia. In the case of manganese it is estimated that it may be 10 years before exploitation of sea resources could be competitive; however, since this is a strategic material it is possible that the United States will wish to develop the capability sooner. The problem is that the United States has few native sources of this material and must rely upon importation for its supply, while Russia has two-thirds of the world's known supply. In time of international conflict this dependence could be very tenuous, and this in turn could affect the basic steel industry. Since neither position would be acceptable to our military effort, it is logical to assume that some governmental action will be taken to develop extraction methods for this resource.

There are many other mineral resources to be exploited from the sea. The sea's dimensions and the fact that for innumerable ages rainfall has eroded the land's wealth into the oceans tell us that this is truly a storehouse of riches for man's future needs. Perhaps the most recent dramatic sea-floor mining effort has been the successful diamond mining operation off the western coast of southern Africa.

In addition to the mineral resources, some coastal areas will be able to sink offshore wells for fresh water. Just recently large submarine freshwater springs have been discovered off Florida. And while not a mining operation, the conversion of salt water to fresh water is now receiving considerable governmental attention. Several experimental seawater conversion plants are now in operation.

This cataloging could go on for some time, but it is sufficient to say that the development of the world ocean's food and mineral resources will represent an increasingly important effort of man on his planet as he contends with the forces of famine, poverty, and depletion of our terrestrial resources. With our planet's population doubling by the end of this century, we must look to inner space for the answers; few will come from outer space. Life on this planet evolved from the sea, and now the pressures of civilization are forcing man back into the sea for survival.

I have discussed the importance of the world ocean from the viewpoint of its valuable resources as a kind of starting point that is familiar to most of us. However, the use of most of these valuable resources is in the future. At present we must consider the ocean's importance as a highway of commerce, for along with fishing this was man's first use of the world ocean environment.

OUR NATION IS LINKED WITH THE REST of the world primarily by lanes of maritime commerce. Raw materials and finished goods flow along these arteries of trade, but very few of us have any real appreciation of how very important seaborne products are to the well-being of our nation.

At this point I would ask each of you to guess approximately how much of the world's total trade is carried by ship. Consider your own experience—how many trucks, trains, and airplanes that you have ever seen—and use this as a basis for your guess. The figure is over 99 percent, so the necessity for having a strong merchant marine is quite clear. Unfortunately, our merchant marine is in trouble for about the same reasons as our fishing industry is in trouble. These reasons are high operating costs and obsolete vessels. The Soviet Union, hardly a traditional sea power, has built an impressive merchant fleet since World War II, and its size soon will surpass ours. Most of Russia's fleet is new; most of ours is old. To be a strong sea power we must have both a strong merchant marine and a strong navy; anything less is weakness.

BOTH WORLD WARS DEMONSTRATED what an intense submarine effort can do to seaborne commerce. The submarine campaigns of the Germans in these two wars almost strangled allied shipping in the Atlantic. In the Pacific our Navy's submarine campaign against the Japanese fleet virtually choked off the flow of vital supplies to the home islands of Japan and was a major factor in that country's defeat. The U.S. Navy's role in protecting the vital arteries of seaborne commerce in war and in peace is well documented by history, but its continuing success depends upon many factors.

The threat of the commerce-destroying submarine is still with us, and is, in fact, even more serious today than it was in World War II. This danger has been brought about by two factors. First, the total number of submarines in the forces of the Communist world is much greater than the number possessed by the Germans and Japanese at the height of World War II. Secondly, submarine technology since World War II has improved at a faster rate than has the ability to counterattack submarines. The introduction of nuclear power by the U.S. Navy in 1954 and of the Polaris missile in 1960 have been major factors in this technological advancement, or gap, depending upon your viewpoint. Even though both of these major improvements were introduced by the U. S. Navy, it is axiomatic in military development that it is only a matter of time until our competitors will have essentially the same capabilities. The Soviet Navy now has both nuclear-propelled submarines and a submarine missile capability.

The submarine-launched missile brought a new dimension into the antisubmarine warfare picture. Where once the U. S. Navy had only to contend with the threat of commerce-destroying submarines, it must now concern itself with the threat of a surprise submarine-launched attack on our shores from beneath the sea. The submarine missile has considerable advantage over the land-based missile. First, it, like the submarine, is a weapon of opportunity and need not expose itself until it has to attack. Secondly, until some overt action is made the submarine is virtually impossible to detect within the opaque confines of the ocean's depths. Since the missile-carrying submarine can maintain station close to the enemy coastline, its missile time of flight will be consequently short, with the result that an antimissile defense system would have trouble in detecting and killing the missile. Since the United States has high population densities on its coasts (29 percent of our population lives in this 8 percent of our country), the submarine missile for use against our cities and industrial areas could be relatively unsophisticated. The distance from the launch site to the target would be fairly short.

THESE THEN, ARE THE TWO THREATS to our national security from the ocean—the commerce-destroying submarine and the missile-carrying submarine. The common thread in the problem of detecting and, in wartime, killing these submersibles is a thorough knowledge of the undersea environment, and the application of this knowledge to the improvement of technology.

This knowledge and its application is analogous in land warfare to the possessing of the necessary meteorological, environmental, and geographic knowledge of a potential battle area so that the military planners can utilize every feature of the terrain for best employing their forces and controlling their movements. The more knowledge, the sounder the planning, with the attendant greater chances of a successful campaign. In addition, such knowledge permits the technologist to design machines for work in this environment.

In the ocean environment the situation is much more difficult than on land. First, the sea powers of the world, until very recently, have given little attention to gaining a real knowledge of the ocean battleground. Recently it was estimated that only 4 percent of the sea floor has been adequately mapped. When one considers the difficulties of the mapping process and the size of the unmapped area, it is not hard to see why the oceans have been receiving increasing attention from our military planners in the past few years.

Sea-floor "geography," or topography, is only one of many important environmental factors. It provides the knowledge that can help to determine possible hiding places for enemy submarines and the ability to operate our own submersibles with greater confidence. At present, the actual detection of an enemy submarine is predominantly a function of the use of sonic energy. Since water is opaque to sight and electronic energy, it does not lend itself to the use of radio and radar devices. We must depend on the use of sound through types of sonar (sound navigation and ranging) equipment to detect underwater objects. However, contrary to common thought, the sea is not a quiet place. It is filled with noises from various sources, such as animal life, waves and storms, and suboceanic volcanic activity. Of these three sources the sounds caused by animal life are by far the most troublesome, as many fish forms are excellent imitators of "man-type" noises, such as those made by submarine and ship propellers, hammering and sawing, and whistles; other fish forms generate noise of such level that it is impossible to hear anything else. To oversimplify, the problem is to catalog all zoological noise sources in the ocean and to be able to separate them from possible submarine noises.

THE THIRD MAJOR PROBLEM AREA, in addition to mapping and to zoological noise, is that of the bending of sound rays in water. The result is that we often do not know where we are "looking" when we detect a noise source. Sound propagation, or velocity, is a function of the density of the medium through which it travels. More simply, sound moves faster through a piece of wood than through air. The density of the ocean is not constant, and it is affected by the three factors of temperature, dissolved salt content, and pressure. As these factors cause the water to become more or less "solid," the velocity of sound is unsteady. To accurately determine location of our target we must know where we are looking, which means we must know and be able to predict the condition of the water masses between us and the target. From this information we can calculate the amount of "bending forces" that are distorting the sound beam. Again, this is an oversimplification, as these predictions presuppose an intimate knowledge of the ocean's ever-changing internal weather.

Of course, at very short ranges we can accept many errors. At one mile the effect probably would be to hit the target a few feet from where we are aiming, but we probably would still hit it. Today we are not thinking in terms of one mile, as we were in World War II when this was acceptable against the old diesel-powered, noisy German and Japanese submarines. Today we are faced with a Soviet submarine force that is the largest in the history of submarine warfare and that includes both missile-launching and nuclear submarines.

Also, one must not forget the Red Chinese submarine fleet, which is the fourth largest in the world.

Will Rogers is reported to have said, "It's easy to catch submarines —just boil the ocean." The Navy isn't thinking quite this big, but the problems of extending our traditional seapower into the third dimension, depth, have led to a remarkable acceleration of the oceanographic sciences and technology in the past five to seven years.

Oceanography is the collective term for the application of many scientific disciplines to the ocean environment. Quite correctly, it is not a true science but an interdisciplinary application of many sciences. As a scientific field oceanography is less than 100 years old, and real progress in the magnitude of effort did not begin until the last 10 to 15 years.

The U.S. Navy has been identified with the founding of oceanography as well as with its growth. Lt. Matthew Fontaine Maury, USN (1806-1873), is called the "father of oceanography" in recognition of his pioneering efforts in developing an orderly method for the collection and analysis of oceanographic data and the publication of charts of the ocean's current systems. In the past few years the Navy has supported the majority of oceanographic research in the United States —in 1964 the Navy's proportion was about 62 percent. Naturally, this effort principally is devoted to supporting our national defense structure, but this military oceanography provides a primary by-product through increasing man's knowledge of ocean environment. Without seapower, the United States cannot exercise its will to utilize the oceans' resources for the welfare of all peoples of this planet.

WITH THIS BROAD BUT BRIEF BACKGROUND in place, let us now look at how we are going about the study of this new frontier— what sort of tools are used in this pursuit and what we can get from them.

The ocean scientist has a problem that his land-based colleagues do not have. He is separated from his subject by the opaque barrier of the ocean's surface. Until just a few years ago most oceanographers were unable to enter the environment that they were studying. Instead, they had to rely upon artificial hands and eyes in the form of grab samplers and remotely controlled cameras to analyze, somewhat vicariously, the ocean's secrets. Direct observation was not possible and the oceanographer had to be content with "standing outside" the ocean environment on board his research ship and making his measurements and studies through a groping system of lowered devices. His terrestrial counterpart, of course, has had to do no such thing. The biologist and the geologist are field scientists, and it would be hard to conceive of them doing their work in any way other than by making direct observation at the site of interest. But the ocean biologist or geologist is not quite so fortunate, for he

Matthew Fontaine Maury, whose studies pioneered the science of oceanography. From a portrait by E. S. Hergesheimer in the U.S. Naval Academy; U.S. Navy photo.

largely has to take samples out of context, and from these often remote clues deduce something of the ocean's secrets. Considering the hardships, it is a tribute to these scientists of the sea that we have learned so much about the ocean environment without it having been really visited.

The principal tool of "classical" oceanography is the research ship. Until recently in the United States most of these ships were conversions of Navy vessels, and in most cases the conversions were less than satisfactory. Happily, a few years ago the United States embarked on a shipbuilding program for oceanographic vessels, and we are now in the process of developing the finest research fleet in the world. These floating scientific laboratories are equipped with elaborate facilities and are designed to permit greater production of oceanographic data per unit of time spent at sea. The latest developments in shipbuilding and scientific technology have gone into these new designs to make them as effective as possible. The oceanographers of our country have had plenty of time to think about what they wanted in a built-for-the-purpose ship. As late as 1960 we had not built an oceanographic research ship in about 30 years.

IN THE EARLY 1950's a major improvement in oceanographic research was ushered in with the development of practical SCUBA equipment for the scientist-diver. For the first time the trained mind and the trained eyes of the scientist could directly visit the ocean environment. With the investigator present at the site of interest instead of in a boat above it, he was able visually to integrate a wide variety of events. Through sight, sound, and color he could study specimens in the context of their environment, instead of studying a disjointed fragment brought up on a cable from the depths.

One of the most exciting recent advances in diving technology is the development of underwater habitations for divers that permit them to work outside in the water at the sea floor for prolonged periods of time. Thus far there are three such programs in the world: Edwin Link's Man in the Sea Project (which became part of Ocean Systems, Inc., in January 1965), the U.S. Navy's SeaLab I and SeaLab II projects, and Capt. Jacques Cousteau's CONSHELF project. All have been quite successful. I am sure that many of you have seen Captain Cousteau's award-winning film called "World Without Sun," which documents his program.

An important advantage of the undersea habitation technique is the great reduction in the time it takes for the driver to travel back and forth to the sea floor. As working depths increase the diver actually spends more time traveling than working, to the effect that he spends only a small part of the day's working time actually doing useful work. The travel time is not so much a function of distance as it is of physiology. The human body under high pressures must be brought down to atmospheric pressure at a slow rate to avoid a diver's worst enemy, the bends. The process of adjustment is called decompression, and the time it takes depends upon the depth and duration of the dive. Obviously, if we could send the diver down for a longer period of time, days or weeks, we could avoid this costly loss of time. The three experimental programs that I have just named have done this through providing a complete diver-support system, a significant element of which is an underwater habitation fully equipped with bunks and food where the air pressure inside is the same as sea pressure outside. In this way the divers do not experience the time-consuming pressure changes at the end of each work period. Access to the house is via an opening in the floor, and, since house air pressure and sea pressure are the same, no water enters the living quarters. At present, fresh air, or a gas mixture, and power usually are supplied from the surface, but more advanced units of the sea-floor houses will be self-contained.

Upon completion of his deep-sea project, the diver will be subject to lengthy decompression, but this will be a one-time process instead of an only slightly shorter period of decompression that must be undertaken for each working day. The net result will be a dramatic increase in man's ability to do useful work on the ocean floor.

Some estimates as to future depth capabilities for free diving run to as much as 1,500 feet, but whatever the figure there is no doubt that the frontiers of diving technology have been dramatically advanced.

SCUBA diving equipment requires the user to be fairly agile, and, since it uses air, its practical use at present is limited to a depth of about 200 feet. The deep-submersible research vehicles and chambers have overcome these limitations, and, together with SCUBA and the research ship, they promise to insure our future oceanographic efforts of a full spectrum of capabilities for studies of the world ocean.

THE FIRST EXPLORATORY USES of an undersea vehicle can be credited to Alexander the Great, who in about 333 B.C. descended into the Mediterranean to a very shallow depth where he was able to make direct, if somewhat inaccurate, observations of the marine landscape. Through the centuries that followed, various other diving craft were planned, and some were built, but these, for the most part, were not for science but for salvage of treasure from the ocean floor. I will not list these craft here, as they are well documented in the various ocean "treasure" books.

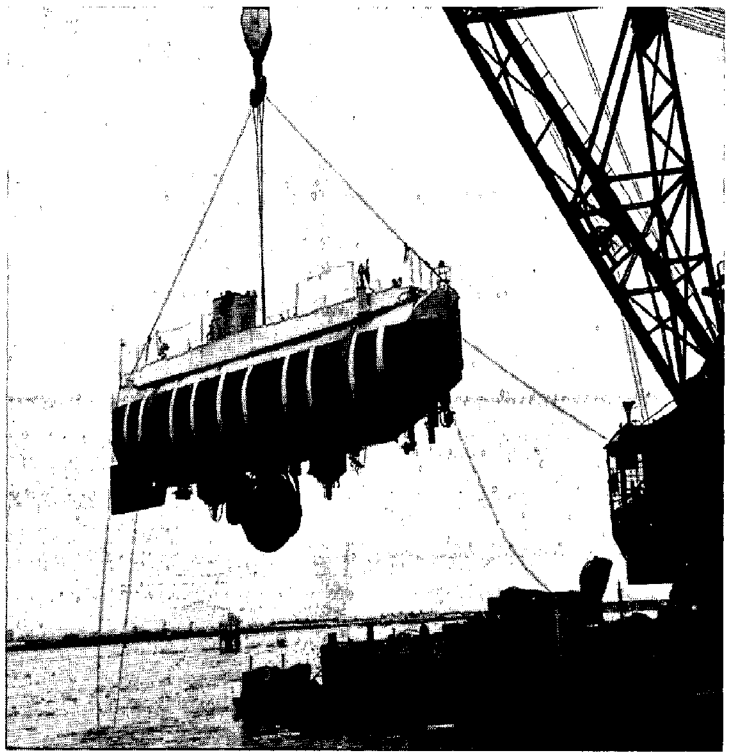
The first really scientific deep-diving vehicle was Dr. William Beebe's *Bathysphere*. Dr. Beebe's operations near Bermuda to a depth of 3,028 feet in 1934 proved the worth of man's entering the undersea environment for direct observation, and it can be said that he was truly the pioneer of this branch of oceanography.

The bathysphere-type vehicle consists of nothing more than a strong steel cabin (sphere) suspended by a cable from a surface ship. Since the cable has weight and the sphere is subjected to the same motion as the mother ship, it can be appreciated that there are definite limitations as to just how much advancement can be made by developing this concept. Prof. Auguste Piccard, a Swiss scientist who achieved fame by his stratospheric balloon ascents in the early 1930's, recognized this problem and ingeniously developed a true "inner spaceship" that was completely free of the ocean's surface and that operated on the principle of the free balloon. Piccard's vehicle was called a bathyscaph, so named after a contraction of two Greek words meaning "deep ship."

Professor Piccard's first bathyscaph, *FNRS-2*, was tested in 1948, and in a later, modified form it was used by the French Navy as the famous *FNRS-3*, which set a world's depth record of 13,287 feet off Dakar, Africa, in 1954. At the time the *FNRS-3* modification was being completed by the French Navy, Professor Piccard was in Italy building a completely new craft based on his experiences with his first vehicle and its evolution into the *FNRS-3*. This new bathyscaph, christened the *Trieste*, was launched in August 1953 at Castellemare di Stabia, Italy, near Naples. For the first five years of its existence the *Trieste* was operated by Professor Piccard and his son Jacques for various scientific and exploratory purposes. In 1958 the *Trieste* was purchased by the U. S. Navy and brought to the Navy Electronics Laboratory at San Diego, California, where it made its first U. S. dive in December of that year. It was at this time that I began my acquaintance with the *Trieste* as its first officer-in-charge, a post that I held from 1959 until 1962.

For five years the bathyscaph *Trieste* operated under the direction of the Navy Bureau of Ships and the Office of Naval Research, carrying out diving programs at San Diego, at Guam, and off Boston, Massachusetts. Perhaps her most famous efforts were the dive to the deepest known place in the ocean in 1960 (nearly seven miles down near Guam) and the search for the lost submarine *Thresher* in 1963. In the first case the *Trieste* project team "claimed" the deepest place in the ocean in the traditional explorer manner by placing an American flag in the Challenger Deep. What is sometimes forgotten in the light of these "heroic" deeds is that this pioneering deep-submersible contributed mightily to man's knowledge of the ocean and to a technology that has permitted the development of other deep-sea research vehicles.

In late 1963 the *Trieste* was retired at the venerable age of 10 years. It is hoped that she will find an honorable home in a museum in recognition for being the pioneer submersible that made the United States first in the conquest of inner space.



The U. S. Navy's bathyscaph Trieste, *holder of the world's depth record of nearly 7 miles. U. S. Navy photo.*

Early in 1964 the new *Trieste II* was launched at San Diego. This new bathyscaph operates in the same fashion as its namesake, but its design reflects the many lessons learned in the five years of Navy operation of the first *Trieste*. During the summer of 1964 *Trieste II* operated at the *Thresher* site 200 miles off Boston Harbor, where pictures were taken of large sections of the *Thresher's* hull structure. Currently, the *Trieste II* is operating out of San Diego in support of various scientific and operational programs of the Navy. This second-generation deep-submersible will certainly add luster to our ocean explorations.

The year 1964 saw several other deep-sea vehicles come into existence in this country. It is probably well at this point to run down the list of some of the U. S. and foreign deep-submersibles, in order of depth capability, to demonstrate just what is in use today.

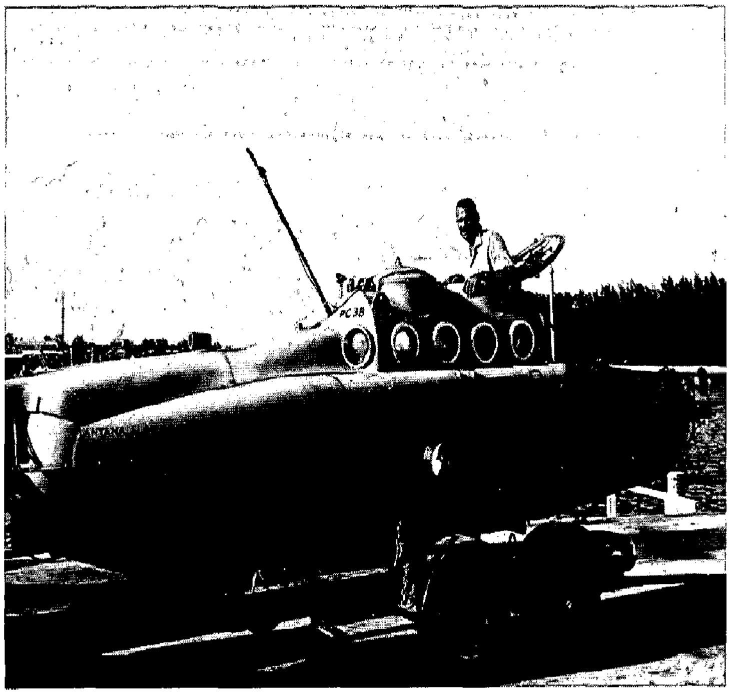
The author (left) on the deck of the Trieste *with Dr. Andreas Rechnitzer, an oceanographer who has accompanied Commander Walsh on many of his dives. U.S. Navy photo.*

Sablefish and hagfish as seen from the bathyscaph Trieste *at 3480 feet in a submarine canyon off California.*

SOME OF THE MOST FAMILIAR VEHICLES are exemplified by the sport-type submarines that are designed to carry a crew of two in tandem down to moderate depths of from 200 to 600 feet. Many of the so-called popular-scientific magazines have featured these miniature submarines. While some of these submarines have been produced by ship manufacturers, there are many more that have come from garages, back yards, and bicycle shops.

Perry Submarine Builders, Inc., has produced a series of small undersea craft called Perry Cubmarines, the latest with a diving capability of 600 feet. The company has about three years of operating experience with these vehicles. In cooperation with Ocean Systems, Inc., a vehicle is being constructed by Perry that will go to 1,500 feet. The existing Perry Cubmarines have a two-man crew with one observer, but the new 1,500-foot-depth vehicle will carry two pilots and two divers.

The Electric Boat Division of the General Dynamics Corporation, which has been building Navy submarines for over half a century, has developed a line of STAR (submarine test and research) vehicles. The STAR II, *Asherah*, was the first functional vehicle in this family. It was launched in 1964 for the University of Pennsylvania and the



Dr. I. E. Wallen, Assistant Director (Oceanography), Museum of Natural History, Smithsonian Institution, in hatchway of a Perry Cubmarine. Photo by Dr. Porter Kier, Smithsonian Institution.

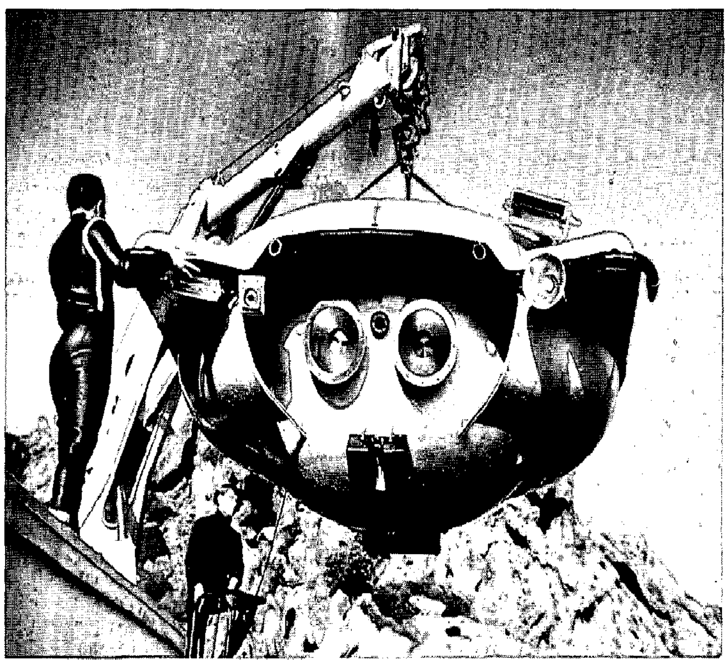
National Geographic Society for use as an exploration vehicle for underwater archeology in the Mediterranean and Aegean Seas. This craft has a two-man crew and is capable of diving to 600 feet. It has proved successful in its operations, and now Electric Boat Division is working on *Star III*, a member of the family that will have a depth capability of 2,000 feet.

Next we come to the Westinghouse-Cousteau family of vehicles. The eminent French underwater explorer and inventor, Capt. Jacques Cousteau, developed his famous *Diving Saucer* in 1959 and utilized it in many feats of exploration. Its success led to an agreement with Westinghouse Corporation to act as U.S. agent and producer of Cousteau's deep vehicles. In early 1964 the *Diving Saucer* began scientific diving operations off the coasts of Southern California and Mexico, operating under the direction of the Westinghouse Deepstar Program. This program provided diving services for many of the oceanographic and research institutions located in Southern California.

The highly maneuverable *Diving Saucer*, carrying a pilot and an observer, is capable of diving to 1,000 feet. As of June 1965, this small, air-transportable submersible had made 355 dives in its six years of operations—a truly amazing degree of usage and a fine comment on the safety of this type of operation.

Captain Costeau has designed a series of deeper diving craft called Deepstar, which, though appearing to be similar to the *Diving Saucer*, is really a new family. The first of this family, the *Deepstar 4000*, will start test dives in mid-1965. It will have a depth capability of 4,000 feet and will carry a three-man crew. As with the *Diving Saucer*, Westinghouse Corporation will handle operations and sales of Deepstar vehicles in the United States. Deeper diving versions of this basic design are planned, though no firm building dates have been established at this time. It is anticipated that the Deepstar series will have the same portability and maneuverability that have made the *Diving Saucer* so successful.

The next vehicle to consider is not presently in service as a scientific tool or workboat, but undoubtedly it is the forerunner of such craft. This vehicle is the *Auguste Piccard*, designed and built by Jacques Piccard and named in honor of his father, the inventor of the bathyscaph. This submersible is a mesoscaph, or middle-depth-submersible, with a depth capability of 2,500 feet. The craft was built for the Swiss National Fair at Lausanne that was held in 1964. It was designed as a tourist attraction—a passenger-carrying inner-spaceship. It carried 40 passengers in airliner-type seats, each with its own



Capt. Jacques Cousteau's Diving Saucer. *Diver at left is wearing a "wet suit," which gives access to shallower ocean depths. National Geographic Society photo.*

window, and was operated by a crew of four, including a stewardess. For 10 dollars the passenger was taken on an hour-long ride beneath the surface of Lake Geneva to its floor at a depth of 900 feet, where the various sights were explained by the crew. The craft was an operational and commercial success. Jacques Piccard recently stated that he hoped to use a similar craft for scientific work in the Gulf Stream.

Next in depth capability is the two-man submersible *Alvin*, named after the noted oceanographer Dr. Allyn Vine of Woods Hole Oceanographic Institution (WHOI) at Woods Hole, Massachusetts. The *Alvin*, sponsored by the Office of Naval Research, will be used extensively to support WHOI programs in the Atlantic Ocean and Caribbean Sea. It is portable to some extent, and is highly maneuverable; its 6,000-foot depth capability gives it a considerable operating range in the span of its average eight-hour dives.

The mid-depth member of the current group of submersibles is the *Aluminaut*, which was launched in 1964 after a six-year design and construction program. Capable of carrying a crew of from four to six to a depth of 15,000 feet for missions of up to 32 hours, the *Aluminaut* was built entirely as a private, commercial venture by the Reynolds Aluminum Company. Its unusual construction features an all-aluminum pressure hull. This vehicle currently is undergoing final trials and should be ready for scientific work in the near future. With its depth capability of 15,000 feet the *Aluminaut* can reach about 62 percent of the ocean's floor.

The real heavyweights of the deep-submersibles are the bathyscaphs. Currently, two are in operation—the French Navy's B-11000, *Archimedes* (*FNRS-3* is in mothballs), and the U.S. Navy's *Trieste II*. These bathyscaphs have the capability of diving anywhere in the world ocean, and thus can cover 100 percent of the ocean's floor.

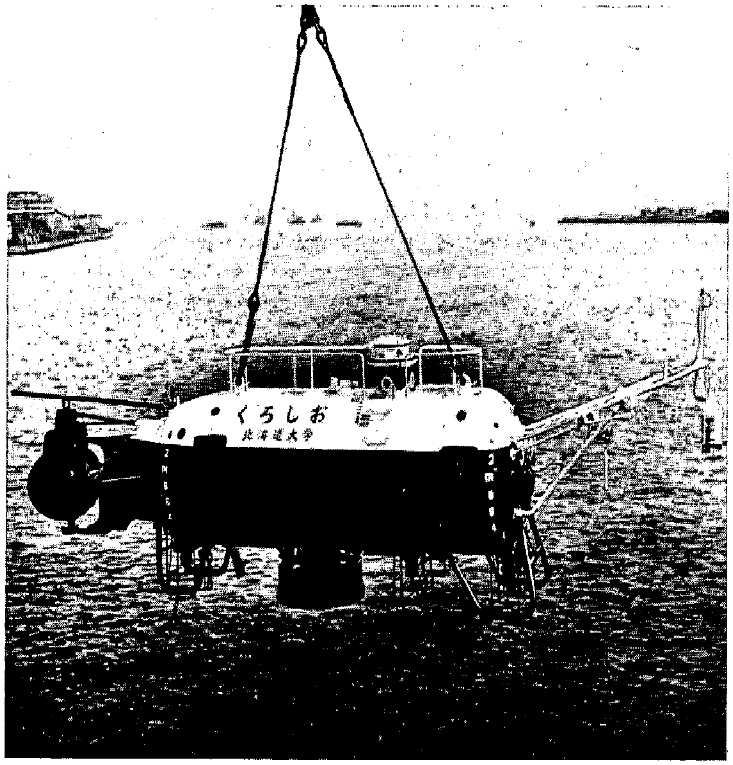
Since its launching in 1961 the *Archimedes* has made dives in the Pacific, Atlantic, and Mediterranean. Operating in some of the deepest trenches in the sea floor, it has been to a depth of 31,350 feet in the Pacific (in 1962), and it can dive in the deepest known spot in the ocean (35,800 feet), although it has not yet made such a dive. Its design was based on experiences with the *FNRS-3*, much as the improved *Trieste II* was based on lessons learned with the operations of *Trieste* from 1958 to 1963. Both the *Archimedes* and the *Trieste II* can be considered second-generation deep-sea vehicles.

The tragic loss of the submarine *Thresher* in 1963 led the Navy to consider its capabilities for locating sunken submarines, rescuing personnel, and conducting salvage operations. A Deep Submergence Systems Review Group was formed to study the problem and to make specific recommendations to the Navy. As a result of this group's study, we now have a Deep Submergence Systems Project (under the Navy Special Projects Office) which, in the span of five years, expects to build a total of five deep-submergence vehicles with eventual depth capabilities of 20,000 feet. This program, though specifically oriented to Navy needs, will create a revolution in the design and construction of small, deep submergence vehicles in the United States. It is estimated that eventually these vehicles will be utilized to a considerable degree for the support of ocean sciences and technology while, at the same time, being maintained in readiness for their primary life-saving mission.

I have not mentioned the many new designs that are on the drawing boards or in preliminary stages of construction. I have also left out some of the vehicles now in operation, as it was not my intention to present a complete catalog of deep-research vehicles or the history of such craft. Rather I wanted to spotlight the significant submersibles that have a demonstrated capability. In any new field such as this, there tends to be more artwork than reality; therefore, I have confined my comments to those significant craft that have either been "wet" or very soon will be immersed.

EXCEPT FOR DR. BEEBE'S pioneering *Bathysphere*, I have not mentioned the tethered submersibles. For shallow depths they are considerably cheaper to build and to operate than a deep-submersible. Of the several craft of this type in existence today, the most successful is the Japanese *Kuroshio II*, owned by Hokkaido University. It is really a tethered submarine, receiving its power from a mother ship but free to maneuver within the limits of its 1,900-foot cable. In case of an emergency it can sever the cable and return to the surface, using power from emergency batteries. This four-to-six-man craft has been used extensively since 1960 in depths up to 650 feet, primarily for fisheries research. It superseded the *Kuroshio I*, launched in 1950. Although the Soviet Union is not known to have an operating, untethered deep-submersible, it has operated a one-man tethered craft successfully for several hundred dives to depths of nearly 2,000 feet.

Another group within the tethered vehicle family is the unmanned submersible, which is useful for some operations—such as object recovery, routine measurements, and some inspection tasks. All of the tethered, unmanned craft in operation employ some form of television and remote manipulators for sighting and handling objects. Control is maintained by an operator located on the mother vessel at the surface. The advantage of this type of craft is that it can be built at less cost and with less of a safety factor, since there is no man inside. Actually, this type of vehicle can be designed to be untethered, though the control problems would then be more difficult. The vast majority of unmanned vehicles are of the tethered type. A notable exception is the three torpedo-like, unmanned, untethered vehicles operated by the Applied Physics Laboratory (APL) at the University of Washington. Simply constructed and successful in operation down to 12,000 feet, they have provided APL with increased capabilities in oceanographic data collection.



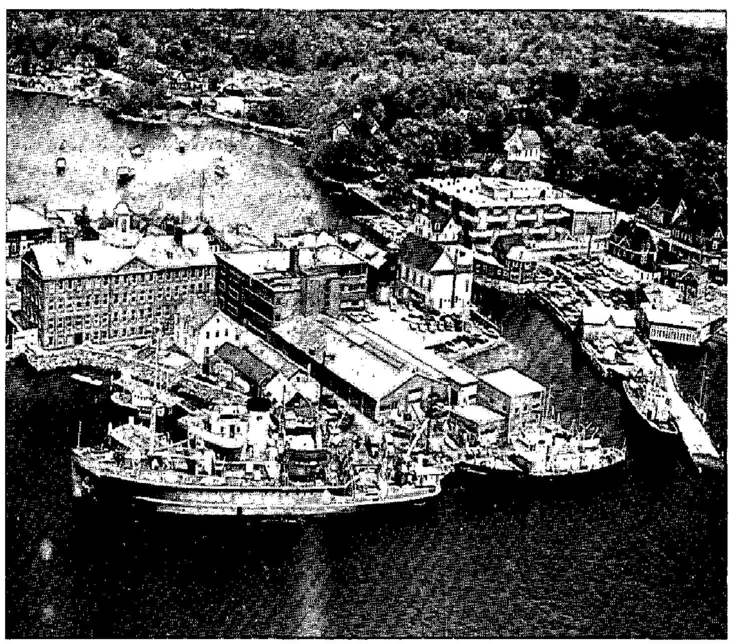
The Kuroshio II, *Japan's tethered deep-submersible.*
Photo by R. D. Terry, Autonetics Corporation.

I HAVE EXPLORED WITH YOU the importance of the world ocean to our national defense and as a source of food and mineral wealth. I have described the ocean's dimensions and what science hopes to learn about its secrets. I have reviewed the types of tools that we are now using to probe these secrets. I admit to considerable oversimplification and omission, as any one of these areas could be a subject for a long lecture; but, as stated earlier, my aim was to give you a broad view of the importance of the world ocean. What remains now is to speak of the future, and its opportunities.

First, the future will find all peoples of our planet increasingly dependent upon the sea as a source of food and mineral supply. We will come to regard the world ocean as one large bowl of nutritious soup whose riches will be developed by a technology capable of competing with terrestrial resources. Beneath the sea we will have farms, giant mining operations, and even homes (suburbia beneath the sea). We will learn economical means of salvaging much of man's works that have been lost in the sea during man's long history of seagoing operations. All of these developments are not far away, and forward-thinking men now are working on plans to accomplish them. I'm positive that a whole new generation of pioneering millionaires will emerge from the conquest of this last geographic frontier on Earth. To mix metaphors, the world ocean will be the future land of opportunity for the forward-looking and the energetic. Success will come from superior knowledge of the ocean environment, progressive technology, and man's pioneering instinct.

Certainly, the rewards are not all materialistic. The greatest opportunity will be for the younger generations of today who are looking for a career. It is estimated that the United States has only 3,000 professional oceanographers with graduate degrees, and that there are probably no more than 8,000 in the world. Imagine, less than 8,000 scientists engaged in exploring 71 percent of our planet! If this is not an opportune field to enter, I don't know what is—with the possible exception of ocean technology, as even fewer people are engaged full time in this work.

THE OCEANOGRAPHIC PROFESSION covers a variety of interests, and it is very satisfying in practice. It is generally recognized to be composed of five basic fields: physical oceanography, marine biology,



One of the important bases for U. S. oceanographic operations is the Woods Hole Oceanographic Institution, pictured here.

marine geology, chemical oceanography, and meteorological oceanography. With few exceptions, training in these fields comes at the graduate level for students who are well versed in the physical, earth, or life sciences. The small number of professionals in this field today means that there is abundant opportunity to participate in the growth of these sciences and to make singular contributions to their advancement. This is true pioneering, whether you are operating a bathyscaph or working in a laboratory. It is a science for those who like to travel because every corner of the world is a work area. The good oceanographer must also be a good mariner, as most research ships do not ride like luxury liners. This field has the advantage of being coeducational, too; almost all of the major oceanographic expeditions today have women scientists included. There is abundant opportunity in this field for the explorer, challenge for the scientist, and adventure for the adventurous.

Of course, the oceanographer does not spend all his time working at sea or sailing about the world. On the average he spends six weeks in the laboratory for every one week on a cruise, as this is about the usual ratio of time spent working up the data to that spent gathering it.

For those more inclined to the field of engineering the opportunities are just as great, for without the engineer the scientist would not have oceanographic ships, deep-submersibles, and instruments. Furthermore, it is the technologist who translates the scientist's knowledge of the environment into useful machines of commerce and national defense.

Schooling in both the ocean sciences and technology is rapidly improving in quality and quantity. Until just a few years ago, only a few institutions taught oceanographic sciences, and none taught ocean engineering. Gradually, the situation is changing. The established institutions have been expanded to meet the increasing demands for education in this field. Naturally, the rate of expansion is tempered by the limited number of people who are available for teaching.

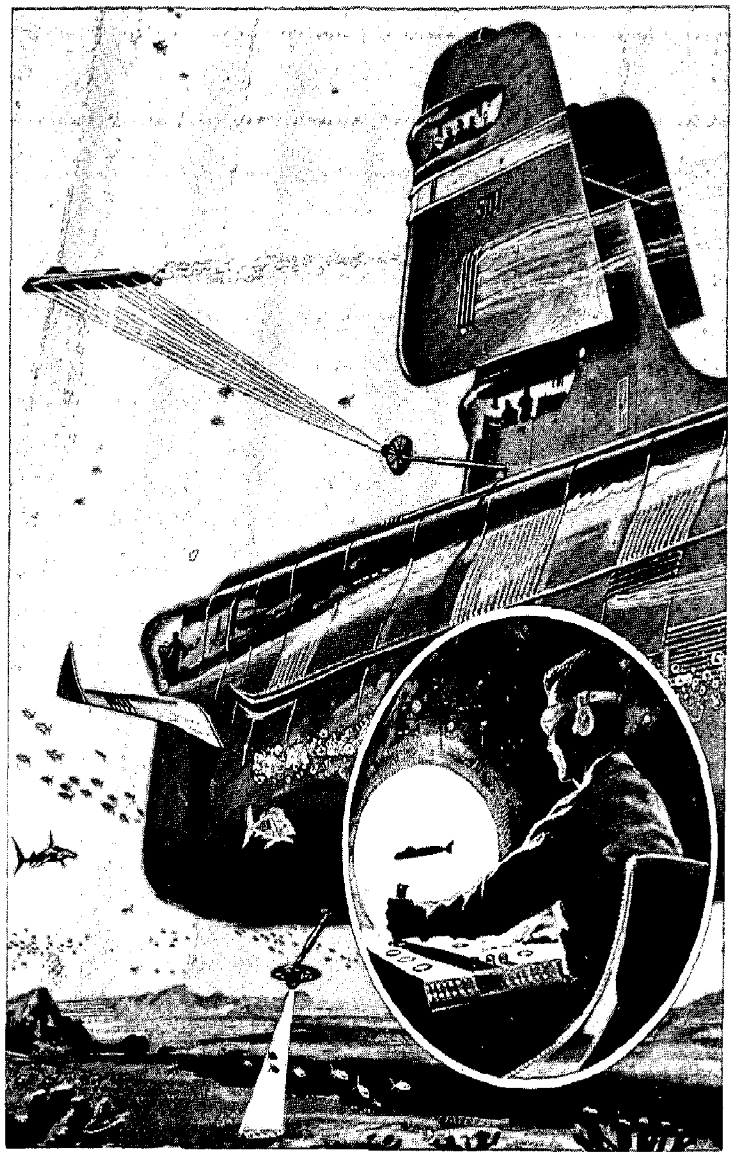
Today there are about 12 institutions in the United States that offer degrees up through Ph.D. in oceanography. Only four institutions offer degrees in ocean engineering and technology. The total annual number of Ph.D.s graduated in oceanography in the past few years has been about 20. Figures for ocean engineering are not quite so easy to define since that field is just getting attention from institutions of higher education. The demand for qualified scientists and engineers is exceeding the supply by a considerable factor. Educational institutions, private and government laboratories, government administration, and industry are all taking their toll in diluting this limited human resource.

The situation in education as it pertains to inner space is extremely fluid and progressive today. There is a good chance that these words and figures on education are obsolete even at this moment. Dramatic progress is being made, but whether it will be of sufficient magnitude to solve the problems of the future is another question. The most important step now is to motivate young people to enter these fields as a career. This can be done on a large scale only if the scientists and engineers in this profession do a more vigorous recruiting job than they have done in the past. Through a public awareness of the importance of the ocean sciences and technology, young people will be influenced into looking into the opportunities offered by the world ocean. There is no doubt as to public awareness of the importance to outer space; we must create the same interest in the world ocean.

IF THE UNITED STATES is to maintain its position of world leadership it must exercise leadership on and in the world ocean, which makes up most of our planet. The science and technology of the oceans require a high degree of priority in our national programs of research, technology, and development. The knowledge of the ocean environment and its technical application cannot be legislated into existence; results will come only from a continuing, orderly national effort. Today we have "good" programs but not many "great" programs, and our total effort needs better definition and direction. We must be competitive in the world ocean, for whoever controls the oceans will also control outer space. It is significant that the only other competitive oceanographic program in the world is that of the Soviet Union. I will not speculate on who is ahead at this instant, but the margin is slim and we know from Sputnik that we can expect new surprises.

One of the major problems facing our nation with regard to inner space is the one of international law. The question of sovereignty over the ocean waters and ocean floor and their resources needs closer consideration. The problems of definition of territorial waters among seagoing nations are still unresolved after two Law of the Sea Conferences (1958 and 1960) of the United Nations. This is a vital issue for fishing interests and for maritime commerce. The two U.N. conferences defined the important right of a nation to the resources of its adjoining continental shelf, but the waters above are still disputed. The ratification of the Continental Shelf Convention in 1964 by the required number of nations gave this convention the force of international law and gave the United States sovereignty over a shelf area four times the size of France.

At this time in our history more and more oceanographers and statesmen are becoming aware of the difficult problems that will face us in extending international law into the three dimensions of the world ocean. With the competitive extraction of ocean resources within the grasp of many of the leading nations it is only a matter of time before serious conflicts can develop as to rights to resource areas and the ownership of claims. At this time one can only imagine that the "law of the six-gun" would be the probable way of working out these conflicts. There are weighty problems ahead for our statesmen and legal experts. These problems must be met soon by the United States



The submarine of the future may employ line-of-sight detection under the sea, using blue-green lasers in identification. Artist: Howard Schafer.

if we are to lead in the use of the world ocean for the good of all nations and the advancement of mankind on this planet.

IN CLOSING, I WANT TO IMPART to you my concern over the role that our nation must play in the exploration and use of the world ocean. To maintain world leadership we must indeed lead the world, and this includes the 71 percent of the world that is covered by water. Our national security depends on our ability to be militarily strong in this area—and strength will come only from superior knowledge and technology. Our future and the future of the poor nations depend on the development and exploitation of the ocean's food and mineral resources, and it is here that our leadership will have the most impact, not only for providing resources for our future but in materially helping to reduce the scourges of famine and poverty among the less fortunate peoples on our planet. We must lead or be led, and the situation will not wait long for our response. I believe that our efforts in the world ocean are as important as our outer space program, for most of mankind will live on Earth, and man will find in the ocean the stuff of which life is made and enriched.

Such a vast commitment will require considerable increases in both material and human resources. The most important consideration is, of course, that of trained manpower—of the personnel resources—and only through demonstration of opportunities in this endeavor can we hope to attract the quantity and quality of men and women needed for the task. The space age was fortunate in that its efforts could begin as an extension of the aircraft industry, where a large technological and scientific pool of talent was available at the beginning. This is not the case in inner space (though considerable interest has been evidenced by the aircraft industry), and such a trained pool must be built the hard way.

The time is now and the place is here, for, as a great sea power by tradition, the United States of America cannot afford to continue at its previous low level of effort. There is no doubt that our national effort has greatly increased in the past five years, but we have just about reached the point where we cannot improve by an order of magnitude without the formulation of national goals in this area and a program that will permit us to reach these goals.

The world ocean is of vital importance to every citizen of our nation, whether he lives on the prairies, in the mountains, or along our coastline. Your active appreciation and interest in our progress here will assist our leadership in finding the best course to follow to insure that the United States is second to no nation in the conquest of inner space.

DATE DUE

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